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IOWA STATE COLLEGE OF AGRICULTURE
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THE USE OF IOWA GRAVEL FOR CONCRETE

BY

T. R. AGG and C. S. NICHOLS

BULLETIN 34
ENGINEERING EXPERIMENT STATION
GOOD ROADS SECTION

Ames, Iowa

Published Tri-Monthly by the Iowa State College of Agriculture and Mechanic Arts. Entered as Second-class Matter, October 26, 1905, at the Post Office at Ames, Iowa, under the Act of Congress of July 16, 1904.

PURPOSE OF THE STATION

THE purpose of the Engineering Experiment Station is to afford a service, through tests and analyses of materials, special investigations, evolution of new devices and methods, and expert advice, first, for the manufacturing and other engineering industries of Iowa; second, for the urban population of the State in solving the technical problems of urban life; third, for the agricultural population and industries of the State in the solution of their purely engineering problems.

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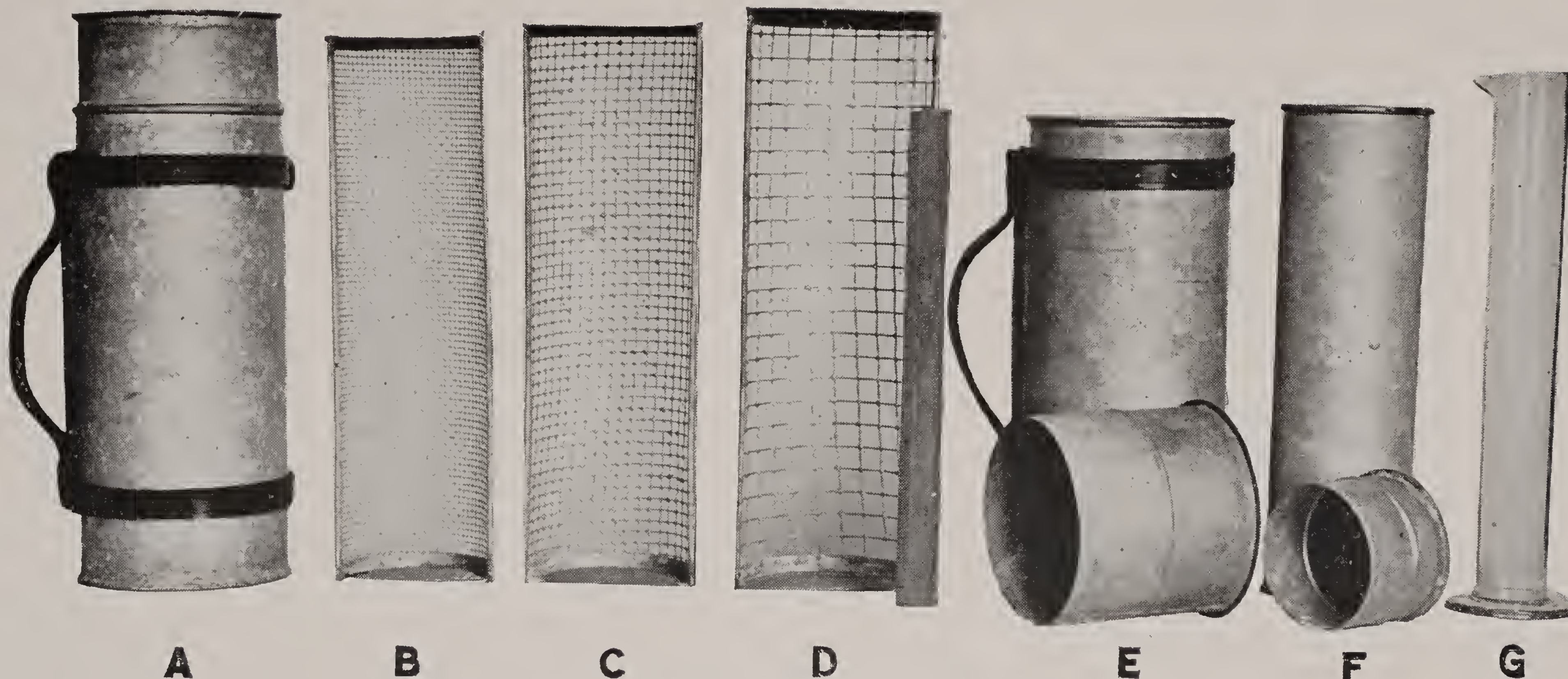
TABLE OF CONTENTS.



FIGURE

THE USE OF IOWA GRAVEL FOR CONCRETE

INTRODUCTION

The survey of deposits of concrete materials which has recently been completed through a co-operative arrangement between the Iowa Highway Commission and the Iowa Geological Survey, shows that the gravels are the most widely distributed and widely used aggregate. The survey also shows that the composition of these gravels is exceedingly variable, particularly as regards the amount and character of sand they contain.

As might be expected when such variable materials are being used, there is a good deal of variation in the quality of the concrete produced. It is for the purpose of supplying in convenient form information which will lead to a more economical use of gravels and a more uniform quality in the concrete produced, that this Bulletin is offered.

Acknowledgements. In the preparation of this bulletin reference has been made to various standard works on concrete and reinforced concrete, especially to Taylor and Thompson's "Concrete, Plain and Reinforced," and to various articles published by Messrs. Fuller, Thatcher and Feret.

The gravels, which are listed in Tables II, III and IV, were collected and analyzed under the joint direction of the Iowa Highway Commission and the Iowa Geological Survey.

The curves used to represent the economy of various mixtures are developed along the line originally worked out by Mr. Clifford Older, Bridge Engineer of the Illinois Highway Commission.

Definitions. The various terms used in the discussion are defined as follows:

Stone.—That portion of a pit run gravel that is retained on a ¼ inch screen.

Sand.—That portion of a pit run gravel that passes a ⅛ inch screen, or a ¼ inch screen, as the case may be.

Pit Run Gravel.—A mixture of sand and gravel in any proportion as it comes from the pit.

Coarse Aggregate.—Pebbles screened from pit run gravel, or crushed stone of a size that is retained on a ¼ inch screen.

Gravel.—Pit run gravel or screened and graded gravel.

Crushed Stone.—Broken stone of any character, crushed and screened over a ¼ inch screen and through a 2½ inch screen.

One Sack Cement.—A sack of cement is assumed to be 0.95 cubic feet.

Measurements are by volume measured loose; that is, shoveled or dumped into the measuring box without tamping or shaking down.

GENERAL PRINCIPLES OF CONCRETE MIXTURES.

It has been established by numerous experiments that the strength of the concrete which is made from any mixture of sand and stone depends primarily upon the ratio of sand to cement in the mixture, so long as the mortar thus made is sufficient in quantity to fill the voids in the stone. The strength of the concrete is not increased by decreasing the amount of stone below the quantity in which the voids will be just filled, nor is it materially decreased.

The exact strength of a concrete made from a mixture of sand and stone will vary considerably with the size and grading of the sand and of the stone. If the sand grains are all very small and the stone pieces all of the same size, a relatively poor concrete will be produced with a given amount of cement. If, on the other hand, the sand ranges in size from $\frac{1}{4}$ inch down and the stone ranges in size from $2\frac{1}{2}$ inches down to $\frac{1}{4}$ inch, both being well graded, a relatively strong concrete can be made with a given amount of cement.

Grading of Aggregates. Numerous investigations have been made to determine the best grading of the coarse and fine aggregates in order to obtain maximum strength in concrete, and practically all the investigations that have been made substantiate the correctness of the theory that an aggregate will give the strongest concrete that can be made with a given amount of cement if the sand and stone when mixed are so graded that the mixture has its maximum density; that is, when the various sized particles exist in such a proportion that the percentage of voids in the aggregate is the smallest that can be obtained with that material. Messrs. Taylor and Thompson, in "Concrete, Plain and Reinforced," give a curve which is a practical adaptation of the theory of maximum density, and concrete made with aggregates graded so that the percentages passing through screens of various sizes will fall on this curve will give the densest, and therefore, the strongest concrete that can be made with that aggregate. This curve is shown in Figure 2. Likewise, considering the best grading for sand and the best grading for coarse aggregate, considered separately, it is found that the curve for maximum density for mixed aggregates can be separated into two parts, one of which represents proper grading for sand, as given in Figures 3 and 4.

There is reason to believe that a good sand should not contain to exceed 10 to 15 per cent. of grains that will pass a screen having 50 meshes per linear inch; the lower end of the sand curve representing cement rather than fine sand grains.

The possibility of grading aggregates in accordance with these curves is somewhat limited and can only be carried out on work of such magnitude as to warrant the expense necessary for securing the various sized aggregates and properly mixing them. On the other hand, for small work it is often possible to approximate the conditions of maximum density by mixing two or more materials and thereby effecting a considerable saving, in the amount of cement necessary to give a concrete of the required strength, over what would be necessary if poorly graded aggregates were used.

Strength of Concrete. In contract work specifications commonly give the range of sizes of "sand" and "stone" and the amount of each that must be used with one part of cement. The specifications must provide first that the proper ratio of sand to cement shall be used so that the concrete will have the desired strength. Just what this ratio shall be depends, to a certain extent, upon the character of the sand, but for sand of fair quality, that is, clean and fairly well graded (not all fine or all coarse, but being a mixture of the two), the strength of various mixtures has been determined by numerous experiments. The following table of average values is given in Taylor and Thompson's "Concrete, Plain and Reinforced:"

TABLE I.

APPROXIMATE AVERAGE CRUSHING STRENGTH OF CONCRETE.

Proportions by Volume			Medium Consistency		Wet Consistency			
			Cubes		Cubes		8x16 in. Cyls.	
			30 Days lb. per sq. in.	6 Mos. lb. per sq. in.	30 Days lb. per sq. in.	6 Mos. lb. per sq. in.	30 Days lb. per sq. in.	6 Mos. lb. per sq. in.
1	1½	3	2800	3700	2600	4100	2300	3600
1	2	4	2500	3300	1900	3100	1700	2700
1	2½	5	2200	2900	1700	2700	1500	2400
1	3	6	1900	2600	1500	2400	1300	2100
1	4	8	1500	2100	1000	1600	900	1400

Concrete Mixtures. In mixing the concrete the cement fills the voids in the sand and coats the grains. This mixture is called mortar. The mortar thus made binds the stone together unless too much stone is used. The volume of mortar made with any mixture, except a very lean one, will usually be a little greater than the volume of sand used.

It will be noted in Table I that the proportion of stone is in every case twice that of the sand. The proportion of stone used does not materially affect the strength of the concrete unless, as previously stated, so much is used that there will be insufficient mortar to fill the voids in the stone. The amount of voids in graded broken stone from which the dust has been removed or in stone screened from gravel seldom exceeds 40%. The mixtures given in Table I provide half as much sand as stone and if the voids in the stone are 40% they will, therefore, be filled and there will be a slight excess of mortar. This excess is desirable because in the process of mixing and placing the concrete the mortar may not be placed in the most advantageous position in the mass, and there will at best be some voids in the concrete after it is tamped in place.

If concrete is to be used for work where a good finish is desired a greater excess of mortar is necessary than the mixtures in Table I provide, and the following are often used:

1-2-3½, 1-2½-4, 1-3-5, etc.

The following mixtures are commonly specified for a few classes of concrete work. This will serve to indicate in a general way the work for which each is suited:

Footings on bridge abutments Brick pavement base	1-3-6, or 1-3-5.
Abutments, piers and headwalls Brick pavement base, foundations	1-2½-5, or 1-2½-4.
Reinforced concrete of all kinds, such as culverts, tanks, bridge floors, walls, one course pavements	1-2-4
Hand rails, girders, one course pavements, one course sidewalks, and work to take a good smooth finish	1-2-3½

THE SIEVE ANALYSIS OF GRAVELS.

The first step in the investigation of a gravel is to determine the relative amount of sand and stone and the grading of each. This is done by means of the sieve analysis. For important work upon which a large amount of material is to be used it would be desirable to use ten sizes of sieves for the sand and the same number for the stone. But for work upon which only a few hundred cubic yards of material is to be used it is unnecessary to make such a complete analysis of the gravel. A small portable testing outfit will usually enable the user to make all of the examination required.

Gravel Testing Outfit. In Figure 1 is shown a gravel testing outfit which is used by the inspectors of the Illinois Highway Commission. Similar outfits can be made by any tinsmith for about $3.50, or can be obtained from the Iowa Highway Commission at actual cost, which is about $3.50.

The outfit is made of galvanized sheet iron and galvanized screen wire and consists of the following parts:

B. A 1/8 inch sand screen.

C. A 1/4 inch sand screen.

D. A 1/2 inch screen for stone.

E. A measuring vessel 4 inches in diameter and 10 inches deep. It has a cover which is shown lying beside the vessel.

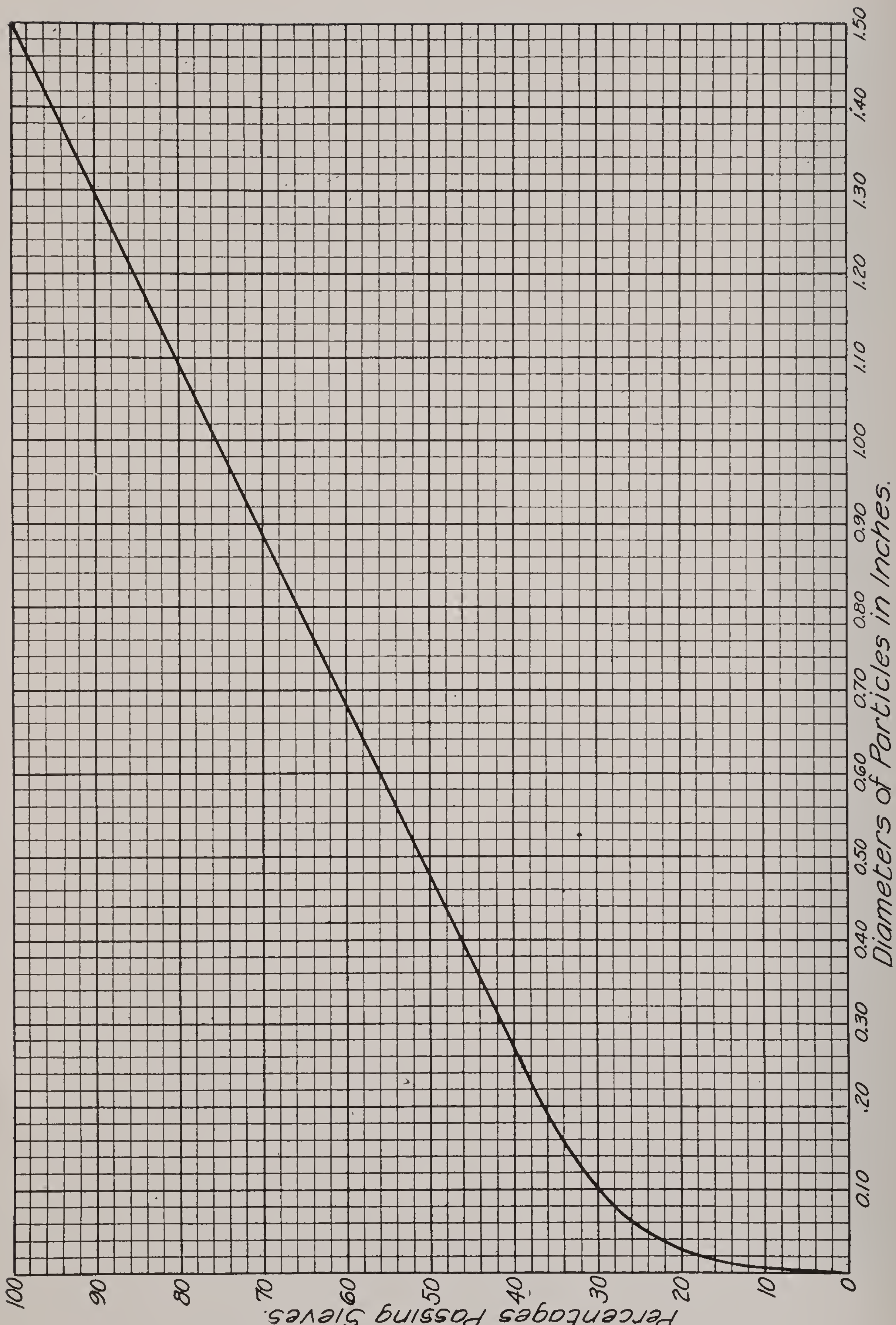
F. A tube for protecting the glass graduate used for clay tests. The capacity of the tube F should be 50% that of the measuring vessel E, i. e., in the ratio of sand to stone commonly specified.

G. A glass graduate 12 inches high and about 2 inches in diameter which is used for the clay test.

The tube which protects the glass graduate fits inside the 1/8 inch screen and the three screens nest together and fit inside the measuring vessel. The outfit, packed for carrying, is shown at A.

Sampling Gravel. Obviously, the whole value of a test depends upon securing a representative sample for analysis. The sample should, therefore, be taken with great care. If taken from a stock pile of material, a quantity of gravel should be taken from a number of different places in the pile and the amount thus secured carefully mixed and spread into a circular pile and then reduced to the proper size for testing by repeatedly quartering. Several samples thus tested will indicate the accuracy of the results being obtained. If the sample to be tested is taken directly from a pit, the appearance of the pit must be carefully studied and the sample secured by taking portions from different places in the pit in such a manner as to obtain a representative sample, and one which will be similar to the material which will eventually be hauled from the pit. These preliminary samples will be sufficient to indicate the general character of the materials, but if the gravel is hauled to a new location before being used the preliminary tests should not be used as a basis for proportioning the aggregate for concrete. When the material has been hauled to the place where the concrete is to be mixed it should be examined and tested and exact proportions for the concrete determined upon the material which is actually to be used in the concrete. It will be found necessary to make frequent tests upon the gravel as the work progresses if its quality varies to any appreciable extent.

Sieve Analysis. Having collected a sample of the gravel which is thought to be representative, the large sheet-iron measure (E in Figure 1), which is 10 inches high, should be filled with the gravel to be tested and shaken down until no more can be added. If the test is for the determination of the proportion of 1/4 inch sand in the aggregate, then the material



Diameters of Particles in Inches.
0.10
.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
1.10
1.20
1.30
1.40
1.50
Percentages Passing Sieves.
0
10
20
30
40
50
60
70
80
90
100

FIGURE 2

contained in the measure is screened through a ¼ inch screen and the two fractions thus obtained placed successively in the measure, thoroughly shaken down and the amount recorded. Since the container is of uniform diameter, the volume will be proportional to the height of the material in it. For example, if it is found that there are 6 inches of sand in the container, the percentage of sand would be 60 and if there were 5 inches of the stone the percentage of stone would be 50. These percentages, when added together, give 110%, as will be noted.

In making the sieve analysis by volumes it will always be found that since the fine aggregates fill in the voids between the coarse aggregates when the two are mixed together, the sum of the volumes of the two when separated will be somewhat greater than the volume of the two mixed. Therefore, it will be found that the percentage of the two fractions added together will range from 110 to 125, depending upon the character and relative percentages of voids of the two parts into which the pit run gravel has been separated.

If it is decided in addition to determining the proportion of sand in the bank gravel, to determine the grading of the sand, then the sand itself may be screened through the ⅛ inch screen and the proportion of material which is retained on, and passes through the ⅛ inch screen measured, which gives an indication of the grading of the sand itself. Likewise, it may be desirable to determine the grading of the coarse aggregates by screening it through the ½ inch screen. If the percentage of ⅛ inch sand is desired it can be determined by using the ⅛ inch sand screen instead of the ¼ inch. By referring to the curves in Figures 3 and 4 the grading of the sand can be checked.

Clay Tests. An approximate determination of the amount of clay or loam in an aggregate may be made as follows: Fill the glass graduate (G in Figure 1) about half full of the aggregate which is to be tested and then add water until the graduate is about three-fourths full, thus leaving a space at the top of the graduate unfilled. The graduate is then shaken for at least 5 minutes so as to give time for the water to wash off all clay or loam from the particles of the aggregate. After the graduate has been shaken it is suddenly turned right-side up and set aside to allow the clay to settle. The clay or loam will settle on the top of the aggregate and may be measured after the water clears. The layer of clay thus deposited will vary in thickness depending upon the length of time it is allowed to settle as it tends to become more compact the longer it stands. If the measurement is made soon after the test is completed, that is, after it has stood for only a few minutes, a larger proportion of clay will show than if the measurement is made after the clay has stood for some time. It has been found by experiment that if the clay has been allowed to stand for three hours, the percentage will then be approximately four times the quantity that would be obtained if the clay should be removed and evaporated to dryness. Therefore, it may be assumed for ordinary practice that the percentage of clay at the end of 3 hours is 4 times the dry percentage, and if the limit of clay by dry measure is 3 per cent, then there may be permitted by the method outlined above, 12 per cent of clay in an aggregate. This method is not exact, on account of the fact that water containing clay has settled into the voids of the aggregate in the lower portion of the graduate, but will serve unless the test thus made shows a percentage of clay near the allowable limit, in which case the exact test should be made.

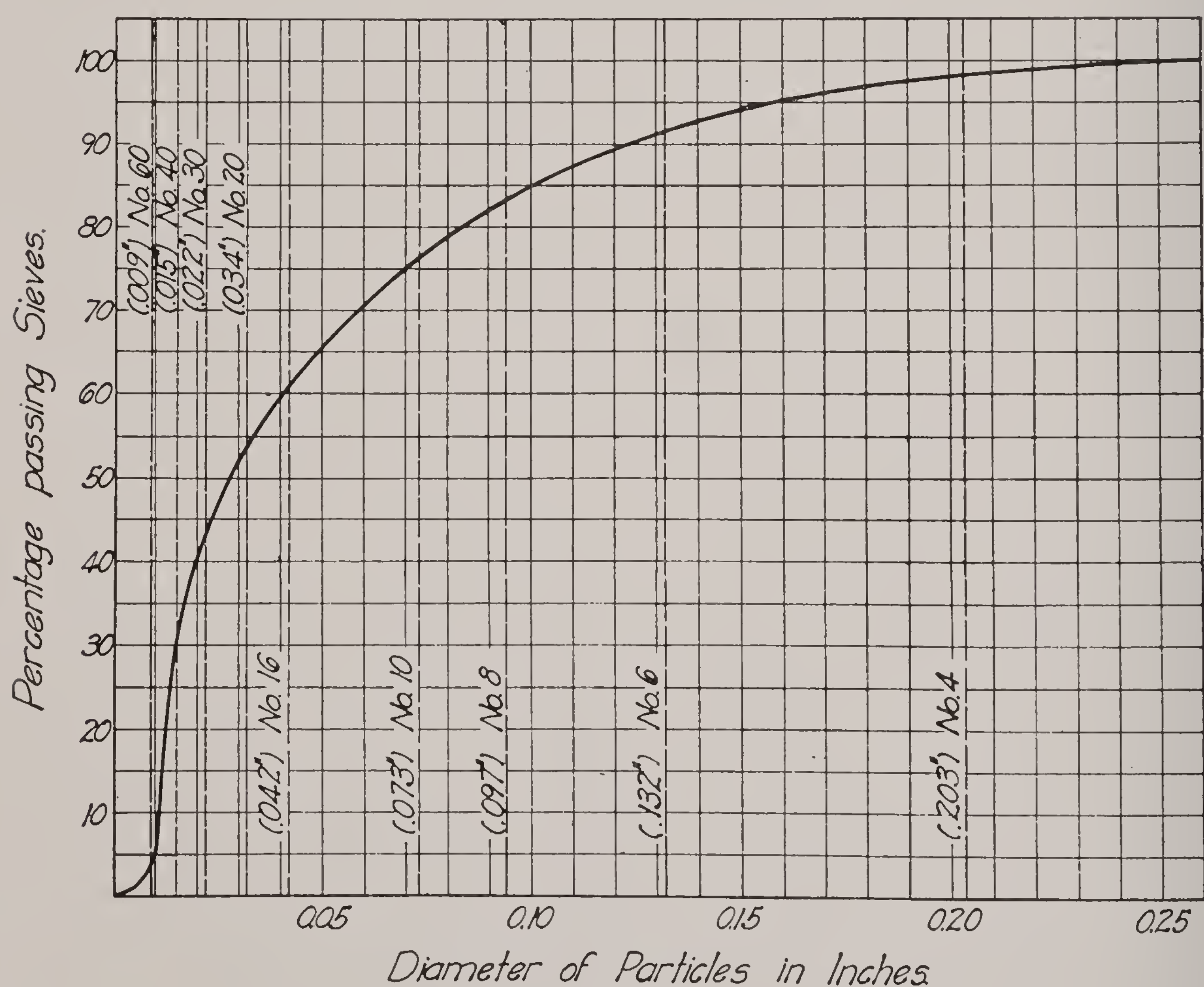


FIGURE 3

If it is desired to get exact results, all the clay must be washed out of the gravel, the washings collected together and evaporated to dryness. The clay content can thus be accurately determined.

Value of Sieve Analysis. There are many uses to which the sieve analysis is put. One is to determine with a given pit run gravel the amount of cement necessary to make concrete to meet a given specification. Another is to determine the amount of coarse aggregate or fine aggregate to add to a given bank gravel in order to give a mixture graded in accordance with a given specification. In other cases the mechanical analysis may be used to determine from among a number of available aggregates the one that is best graded, or the best possible combination of two or more gravels for a given structure or for a given specification.

CONCRETE MADE WITH PIT RUN GRAVEL.

It frequently becomes necessary to make concrete from pit run gravel and it is common practice to specify an arbitrary mixture such as 1 to 4, or 1 to 6.

A 1 to 4 concrete made from pit run gravel from one pit will differ in strength very much from a 1 to 4 mixture of pit run gravel from some other pit unless the two gravels happen to be very much alike as to the sand content.

A specification such as 1 part cement to 4 parts pit run gravel means nothing unless the allowable percentage of sand in the pit run gravel is also specified. It is generally assumed that a mixture of one part cement to four parts pit run gravel is equivalent to a mixture of one part cement to two parts sand and four parts stone. As a matter of fact they are not equivalent unless the volume of sand in the pit run gravel is just half the volume of the stone.

It is apparent, then, that in making concrete from pit run gravel there must be some basis for proportioning that takes account of the varying percentages of sand in the gravel. The great variation in this factor can readily be seen by an examination of Tables II, III and IV, which give the results of sieve analyses made on a number of Iowa gravels.

Referring again to the general principle that the strength of concrete depends primarily upon the ratio of sand to cement and applying that criterion to the proper proportioning of concrete made with pit run gravel, it may be stated that the amount of cement to use with any pit run gravel for a concrete of any desired strength can only be decided upon after the sand content of the gravel is known.

If the pit run gravel is to be used for making the concrete for bridge piers or for a pavement base, where a mixture of 1-2½-5 would be specified if crushed stone or screened gravel and sand were available, the amount of cement to be used with the pit run gravel would be that which would make with the sand in the gravel a 1 to 2½ mortar. The amount of stone in the gravel does not influence the amount of cement to be used, but if the volume of stone in the gravel were more than twice the volume of the sand some of the stone should be screened out. If the volume of stone in the pit run gravel is less than twice the volume of sand that does not materially decrease the strength of the concrete, so long as the ratio of sand to cement is kept constant. The amount of concrete obtained with a sack of cement in this latter case will, however, be less than if the volume of stone were just twice the volume of sand, and the amount of cement used per cubic yard of gravel would, therefore, be greater than if the sand and stone were in the proper relative proportion.

From the foregoing it is apparent that concrete made of pit run gravel and cement in proportions arbitrarily chosen without regard to the sand content of the gravel will not be uniform in strength nor will its exact strength be known beforehand. To use such concrete in structures of any magnitude or importance is dangerous and uneconomical. Even with the greatest care in the selection and grading of the aggregate and mixing the concrete there will be some variations in the strength of different batches of concrete made at different times, and it is important to avoid all known causes of variation in strength.

Sand. Since the amount of sand in a pit run gravel determines the amount of cement that must be used, it becomes of considerable importance to know just what part of the mixture shall be called sand. It has become common practice to consider as sand that portion of pit run gravel that will pass through a ¼ inch screen, and most plants furnishing sand on a commercial scale have their screens arranged in that way. If, however, the matter is considered from the standpoint of scientific grading of the fine and coarse aggregates ("sand" and "stone") the maximum size of the particles of sand should vary with a variation in the maximum size of the pieces of coarse aggregate. If the coarse aggregate is graded up to 2½ inches, then ¼ inch sand would be the best, but if the coarse aggregate is graded up to 1¼ inch, then sand graded from about ⅛ inch down would probably be best.

Since most of the pit run gravel used in Iowa contains very little material above 1½ inch in size, theoretically the sand should be graded from about ⅛ inch down, but should be screened through a larger sized screen for use with crushed stone of the 2 inch size, or coarser. It is not necessary or desirable on small work to vary the sand screen for each deposit of gravel, even if the maximum size of stone does vary, because the grading of the material otherwise is not uniform enough to warrant such great refinement in the size of the sand. If sand from ⅛ inch down is used it should be reasonably well graded. that is, it should fall somewhere near the curve for ⅛ inch sand given in Figure 4. Just how much variation would be permissible cannot be definitely stated from the data at hand,

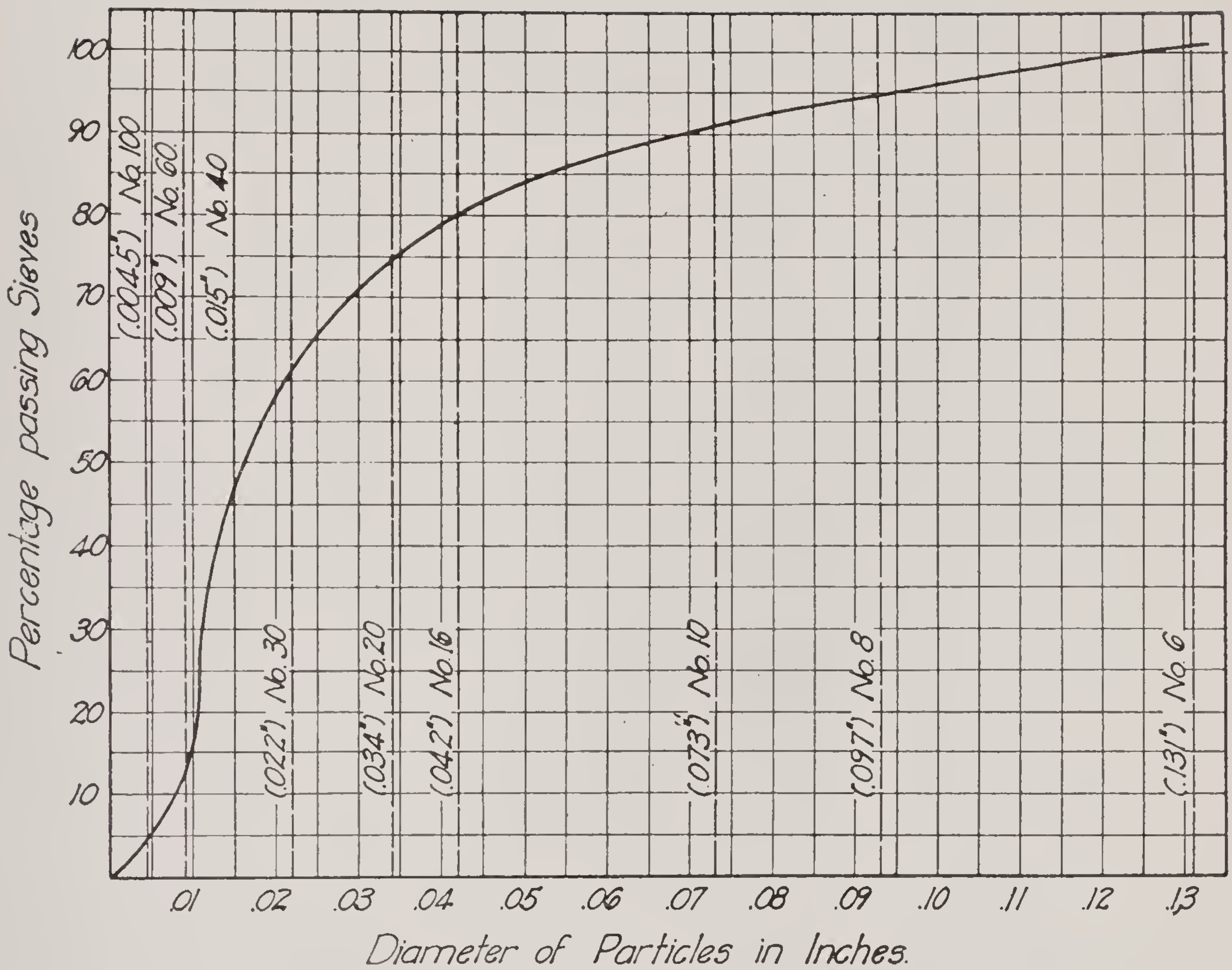


FIGURE 4

but good results have been repeatedly obtained when the percentage of the 1/8 inch sand which passed a 1-16 inch screen was as little as 65% and where it was as great as 85%.

The results of the analyses given in Tables II, III and IV have been separated into the three groups on the following basis:

Group 1, which is listed in Table II comprises pit run gravel in which the grading of the 1/8 inch sand is within the limits above mentioned if screened through a 1-16 inch screen. With pit run gravels of this type it is believed that concrete may be safely proportioned on a basis of the amount of 1/8 inch sand contained therein.

Group 2, listed in Table III, comprises pit run gravels in which the 1/8 inch sand is poorly graded, that is, the percentage of the sand which passes a 1-16 inch screen is either greater than 85%, or less than 65%. In the majority of cases it is greater than 85%, which is to say that the sand is fine. But if the sand is screened through a 1/4 inch screen it is found to be reasonably well graded. Pit run gravel of this type should be used with care on important work, the amount of cement used being based upon the amount of 1/4 inch sand contained. It is not safe, in the light of present knowledge, to mix concrete on a basis of the 1/8 inch sand contained in gravels of this type and in any case it would be best to screen and reproportion the material.

The following tables are illustrative of the results that may be expected when the sieve analysis is made on pit gravel. It should be noted that the per cent of sand and stone has been determined by weight and not by volume, and for purposes of comparison the percentage of sand should be used. The percentage of stone is not comparable with results of test made by volume measure.

The column headings are self explanatory.

TABLE II.

Sample Number	Percentage of Stone (Above 1-8 in.)	Percentage of Sand (Passing 1-8 in.)	Percentage of Sand Passing 1-16 in. Screen	Ratio of Sand to Stone	Voids		Percentage of Clay	Cement per Cu. Yd. Concrete, Using Pit Run Gravel			Cement per Cu. Yd. Concrete, Using Screened and Reproportioned Gravel			Cu. Yds. Pit Run Gravel to Screen to Secure Mat. for 1 Cu. Yd. Concrete	Cu. Yds. Stone or Sand to Add to Provide Materials for 1 Cu. Yd. Concrete	LOCATION OF PIT
					Sand	Stone		Sacks	Bbls.	Cost $1.50 Bbl.	Sacks	Bbls.	Cost $1.50 Bbl.			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
1	16	84	81	5.25	35	38	1.71	12.00	3.00	4.50	6.00	1.50	2.25	3.75	0.728	Maquoketa.
6	8	92	75	11.50	40	41	3.60	13.00	3.25	4.90	6.00	1.50	2.25	7.50	0.789	Red Oak.
8	12	88	78	7.33	34	34	1.69	12.50	3.13	4.70	6.00	1.50	2.25	5.00	0.760	Pacific Junction.
15	38	62	74	1.63	36	35	1.24	8.90	2.21	3.32	6.00	1.50	2.25	1.58	0.480	Lansing.
19	21	79	80	3.76	36	41	3.14	11.25	2.82	4.24	6.00	1.50	2.25	2.86	0.684	Correctionville, Gilleas Pit.
21	34	66	71	1.94	34	37	2.06	9.40	2.35	3.53	6.00	1.50	2.25	1.76	0.537	Sac City, Robbins Pit.
22	20	80	80	4.00	35	39	1.30	11.40	2.85	4.27	6.00	1.50	2.25	3.00	0.693	Early, Early Con. & Stone Co.
23	34	66	66	1.94	35	34	4.10	9.40	2.35	3.52	6.00	1.50	2.25	1.76	0.537	Sioux Rapids, Salverson Pit.
26	32	68	78	2.12	36	40	2.25	9.70	2.42	3.63	6.00	1.50	2.25	1.88	0.563	
27	24	76	82	3.16	32	38	1.90	10.80	2.70	4.05	6.00	1.50	2.25	2.50	0.654	Doon, Miller & Montgomery Pit.
32	24	76	82	3.16	36	37	2.02	10.80	2.70	4.05	6.00	1.50	2.25	2.50	0.654	Farmington.
38	24	76	77	3.16	35	34	1.41	10.80	2.70	4.05	6.00	1.50	2.25	2.50	0.654	Eddyville.
45	36	64	78	1.78	34	36	5.10	9.10	2.28	3.42	6.00	1.50	2.25	1.67	0.509	Belmond.
46	21	79	75	3.76	33	35	2.64	11.25	2.81	4.22	6.00	1.50	2.25	2.86	0.684	Eagle Grove, Boone River.
50	18	82	73	4.55	37	34	1.40	11.70	2.92	4.38	6.00	1.50	2.25	3.23	0.720	Jefferson, Coon River.
51	32	68	73	2.12	32	33	4.00	9.70	2.42	3.63	6.00	1.50	2.25	1.88	0.563	Grand Junction, 3 miles northwest town.
53	44	56	75	1.27	33	35	3.10	8.00	2.00	3.00	6.00	1.50	2.25	1.36	0.378	Clemons, Lundon Pit.

54	22	78	79	3.54	36	35	1.17	11.00	2.75	4.13	6.00	1.50	2.25	2.73	0.674	Muscatine County, Orono Twp., 20-21.
57	32	68	77	2.12	28	30	3.30	9.70	2.42	3.63	6.00	1.50	2.25	1.88	0.563	Ft. Dodge, bench sand.
62	37	63	81	1.70	25	26	3.52	9.00	2.25	3.38	6.00	1.50	2.25	1.62	0.495	Ames, College Pit.
63	31	69	83	2.23	25	26	3.35	9.80	2.45	3.68	6.00	1.50	2.25	1.93	0.576	Pilot Mound.
64	24	76	75	3.16	33	40	3.33	10.80	2.70	4.05	6.00	1.50	2.25	2.50	0.654	Montour.
66	43	57	77	1.35	36	43	5.33	8.10	2.03	3.05	6.00	1.50	2.25	1.40	0.397	Vinton.
67	14	86	84	6.15	28	41	11.50	12.30	3.04	4.56	6.00	1.50	2.25	4.28	0.744	Vinton.
68	46	54	72	1.18	22	40	4.72	7.70	1.92	2.88	6.00	1.50	2.25	1.30	0.340	Waverly.
69	10	90	84	9.00	37	42	3.33	12.80	3.20	4.80	6.00	1.50	2.25	6.00	0.775	South Amana.
70	25	75	78	3.00	36	40	2.66	10.70	2.69	4.00	6.00	1.50	2.25	2.40	0.644	Cedar Falls.
71	42	58	80	1.38	30	43	12.50	8.25	2.33	3.04	6.00	1.50	2.25	1.43	0.415	Wellsburg.
72	24	76	82	3.16	34	59	2.50	10.80	2.70	4.05	6.00	1.50	2.25	2.50	0.654	Correctionville.
74	34	66	71	1.94	33	41	3.67	9.40	2.33	3.50	6.00	1.50	2.25	1.76	0.537	Paullina.
75	38	62	81	1.63	37	45	4.67	8.90	2.20	3.30	6.00	1.50	2.25	1.58	0.480	Osage.
76	60	40	74	0.67	32	41	6.84	6.00	1.50	2.13	6.00	1.50	2.25	--------	0.020*	Dumont.
79	33	67	68	2.03	33	42	9.34	9.50	2.38	3.57	6.00	1.50	2.25	1.82	0.576	Ionia.
81	33	67	76	2.03	28	39	6.67	9.50	2.38	3.57	6.00	1.50	2.25	1.82	0.576	Charles City.
82	25	75	83	3.00	31	37	9.50	10.70	2.69	4.00	6.00	1.50	2.25	2.40	0.644	Rock Rapids.
83	25	75	83	3.00	30	38	5.33	10.70	2.69	4.00	6.00	1.50	2.25	2.40	0.644	Dows.
84	22	78	79	3.54	33	40	5.00	11.00	2.72	4.05	6.00	1.50	2.25	2.73	0.674	Sheffield.
85	48	52	72	1.08	32	42	3.33	7.40	1.85	2.78	6.00	1.50	2.25	1.25	0.297	Wright.
87	47	53	78	1.13	33	40	12.30	7.50	1.88	2.82	6.00	1.50	2.25	1.28	0.318	Kamrar.
89	44	56	74	1.27	27	41	3.17	8.00	2.00	3.00	6.00	1.50	2.25	1.36	0.378	Grundy Center.
90	15	85	73	5.66	33	40	7.16	12.00	3.00	4.50	6.00	1.50	2.25	4.00	0.750	Webster City.
91	9	91	76	10.01	30	43	5.66	13.00	3.25	4.87	6.00	1.50	2.25	6.67	0.782	Mapleton.
92	40	60	83	1.50	31	45	4.50	8.50	2.13	3.20	6.00	1.50	2.25	1.50	0.448	Hampton.
93	45	55	70	1.22	34	41	4.50	7.80	1.95	2.93	6.00	1.50	2.25	1.34	0.360	Ackley.
94	28	72	74	2.57	34	36	2.50	10.30	2.54	3.81	6.00	1.50	2.25	2.15	0.611	Pisgah.
95	46	54	69	1.17	------	------	--------	7.70	1.92	2.88	6.00	1.50	2.25	1.30	0.330	St. Anthony.
101	25	75	67	3.00	37	37	3.20	10.70	2.67	4.00	6.00	1.50	2.25	2.40	0.644	Grand Junction, C. & N. W Ry. Pit.
102	44	56	65	1.27	46	47	9.30	8.00	2.00	3.00	6.00	1.50	2.25	1.36	0.378	Boone, Moen Pit.
103	31	69	76	2.23	34	34	2.20	9.90	2.48	3.72	6.00	1.50	2.25	1.93	0.576	Boone, Moen Pit.
107	31	69	69	2.23	34	------	1.84	9.90	2.48	3.72	6.00	1.50	2.25	1.93	0.576	Algona, Ferguson Pit.
108	37	63	67	1.70	29	30	2.22	9.00	2.25	3.37	6.00	1.50	2.25	1.62	0.465	Jefferson.
109	42	58	74	1.38	29	29	3.31	8.25	2.06	3.09	6.00	1.50	2.25	1.43	0.415	Jefferson.
111	20	80	83	4.00	31	32	3.33	11.30	2.83	4.25	6.00	1.50	2.25	3.00	0.693	Marshalltown.
120	55	45	71	0.82	32	33	2.56	6.40	1.60	2.40	6.00	1.50	2.25	1.09	0.122	DeWitt.
124	31	69	73	2.23	32	32	8.04	9.90	2.48	3.72	6.00	1.50	2.25	1.93	0.576	Sioux City.
131	90	10	85	0.11	------	------	--------	--------	------	------	6.00	1.50	2.25	--------	0.320*	Ottumwa.

*Sand to add.

TABLE III.

Sample Number	Percentage of Stone (Above 1-8 in.)	Percentage of Sand (Passing 1-8 in.)	Percentage of Sand Passing 1-16 in. Screen	Ratio of Sand to Stone	Voids		Percentage of Clay	Cement per Cu. Yd. Concrete, Using Pit Run Gravel			Cement per Cu. Yd. Concrete, Using Screened and Reproportioned Gravel			Cu. Yds. Pit Run Gravel to Screen to Secure Mat. for 1 Cu. Yd. Concrete	Cu. Yds. Stone or Sand to Add to Provide Materials for 1 Cu. Yd. Concrete	LOCATION OF PIT
					Sand	Stone		Sacks	Bbls.	Cost $1.50 Bbl.	Sacks	Bbls.	Cost $1.50 Bbl.			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
2	56	44	45	0.79	33	42	5.03	6.25	1.56	2.34	6.00	1.50	2.25	1.07	0.100	DeWitt, City Pit.
3	26	74	53	2.85	37	40	7.78	10.60	2.65	3.98	6.00	1.50	2.25	2.31	0.634	Clermont.
7	66	34	42	0.52	36	40	7.21	-------	-----	-----	6.00	1.50	2.25	-------	0.080*	Clermont.
13	42	58	90	1.38	39	46	1.35	8.30	2.08	3.12	6.00	1.50	2.20	1.43	0.415	Elkader.
17	49	51	61	1.04	36	38	0.47	7.25	1.81	2.72	6.00	1.50	2.25	1.23	0.275	Clermont, Stahl's Pit.
20	22	78	61	3.54	29	42	7.82	11.00	2.75	4.12	6.00	1.50	2.25	2.73	0.674	Sibley.
28	45	55	63	1.22	30	39	0.63	7.80	1.95	2.93	6.00	1.50	2.25	1.34	0.360	Correctionville, Fleming Pit.
29	28	72	57	2.57	35	35	0.19	10.25	2.56	3.84	6.00	1.50	2.25	2.15	0.611	Ottumwa, river gravel.
35	35	65	90	1.85	36	35	2.09	9.25	2.31	3.47	6.00	1.50	2.25	1.72	0.524	Des Moines County, Flint R. Twp.
40	19	81	90	4.27	35	35	3.04	11.50	2.88	4.32	6.00	1.50	2.25	3.16	0.702	Gifford.
41	54	46	86	0.85	27	28	1.14	6.60	1.65	2.48	6.00	1.50	2.25	1.11	0.150	Albany.
43	43	57	92	1.33	34	35	5.09	8.10	2.03	3.05	6.00	1.50	2.25	1.40	0.397	Hanlontown.
47	38	62	86	1.63	26	27	3.75	8.90	2.23	3.35	6.00	1.50	2.25	1.58	0.480	Hanlontown.
49	37	63	56	1.70	38	33	2.60	9.00	2.25	3.37	6.00	1.50	2.25	1.62	0.495	Denison, Mills Pit.
58	33	67	59	2.03	32	33	10.40	9.50	2.38	3.57	6.00	1.50	2.25	1.82	0.576	Badger.
60	22	78	80	3.55	28	31	2.90	11.00	2.75	4.12	6.00	1.50	2.25	2.73	0.674	
61	46	54	62	1.17	35	35	4.75	7.70	1.92	2.88	6.00	1.50	2.25	1.30	0.340	Lake City.
73	51	49	50	0.96	35	40	1.66	7.00	1.75	2.63	6.00	1.50	2.25	1.18	0.225	Marble Rock.
77	33	67	88	2.03	31	40	5.34	9.50	2.38	3.57	6.00	1.50	2.25	1.82	0.576	
78	30	70	88	2.34	34	40	11.34	10.00	2.50	3.75	6.00	1.50	2.25	2.00	0.588	Storm Lake.
80	48	52	53	1.08	26	37	9.50	7.40	1.85	2.78	6.00	1.50	2.25	1.25	0.297	Missouri Valley.
86	38	62	64	1.63	35	42	5.00	8.90	2.22	3.33	6.00	1.50	2.25	1.58	0.480	Clutier.
88	59	41	51	0.70	35	40	1.50	-------	-----	-----	6.00	1.50	2.25	-------	0.010*	Webster City.
104	38	62	63	1.63	32	32	3.20	8.90	2.22	3.33	6.00	1.50	2.25	1.58	0.480	Boone.
114	40	60	64	1.50	29	29	1.40	8.50	2.13	3.20	6.00	1.50	2.25	1.50	0.448	Muscatine, Mississippi River.
119	55	45	60	0.82	28	29	2.50	6.40	1.60	2.40	6.00	1.50	2.25	1.09	0.122	Anthony.

*Sand to add.

TABLE IV.

Sample Number	Percentage of Stone (Above 1-8 in.)	Percentage of Sand (Passing 1-8 in.)	Percentage of Sand Passing 1-16 in. Screen	Ratio of Sand to Stone	Voids		Percentage of Clay	Cement per Cu. Yd. Concrete, Using Pit Run Gravel			Cement per Cu. Yd. Concrete, Using Screened and Reproportioned Gravel			Cu. Yds. Pit Run Gravel to Screen to Secure Mat. for 1 Cu. Yd. Concrete	Cu. Yds. Stone or Sand to Add to Provide Materials for 1 Cu. Yd. Concrete	LOCATION OF PIT
					Sand	Stone		Sacks	Bbls.	Cost $1.50 Bbl.	Sacks	Bbls.	Cost $1.50 Bbl.			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
4	8	92	87	11.50	33	38	2.32	13.10	3.28	4.92	6.00	1.50	2.25	7.50	0.789	Le Mars, Kramer Pit.
5	33	67	88	2.03	42	46	10.24	9.50	2.38	3.57	6.00	1.50	2.25	1.82	0.576	Clermont, Williams Pit.
9	5	95	93	19.00	37	44	1.93	13.50	3.38	5.07	6.00	1.50	2.25	12.00	0.809	Clarinda.
10	9	91	92	10.20	40	42	1.78	12.90	3.23	4.85	6.00	1.50	2.25	6.67	0.782	Leon.
11	4	96	90	24.00	39	38	4.07	13.70	3.43	5.14	6.00	1.50	2.25	15.00	0.816	DeKalb, South Pit.
12	6	94	94	15.70	37	41	3.03	13.40	3.35	5.02	6.00	1.50	2.25	10.00	0.803	Leon.
14	0	100	100	--------	36	------	1.01	14.20	3.55	5.33	6.00	1.50	2.25	--------	0.840	McGregor, Boyle Pit.
16	1	99	98	99.00	34	38	1.49	14.10	3.52	5.28	6.00	1.50	2.25	60.00	0.834	Dubuque.
18	4	96	88	24.00	34	36	0.52	13.70	3.43	5.14	6.00	1.50	2.25	15.00	0.816	Clermont.
24	20	80	83	4.00	36	42	9.40	11.40	2.85	4.28	6.00	1.50	2.25	3.00	0.693	
25	10	90	88	9.00	30	42	2.30	12.80	3.20	4.80	6.00	1.50	2.25	6.00	0.775	Ida Grove.
30	4	96	91	24.00	37	40	0.44	13.70	3.43	5.14	6.00	1.50	2.25	15.00	0.816	
31	13	87	64	6.68	34	37	0.62	12.40	3.10	4.65	6.00	1.50	2.25	4.61	0.750	Farmington.
33	14	86	91	6.14	30	28	5.50	12.20	3.05	4.58	6.00	1.50	2.25	4.28	0.744	Manchester.
34	2	98	98	49.00	38	34	6.25	13.90	3.48	5.22	6.00	1.50	2.25	30.00	0.828	Oelwein.
36	19	81	94	4.27	42	42	22.68	11.50	2.88	4.32	6.00	1.50	2.25	3.16	0.702	Independence.
37	84	16	24	0.19	33	33	0.63	--------	------	------	6.00	1.50	2.25	--------	0.260*	Clinton.
39	11	89	93	8.09	33	33	4.33	12.70	3.18	4.77	6.00	1.50	2.25	5.45	0.767	Tracey.
42	0	100	100	--------	38	38	0.13	14.20	3.55	5.32	6.00	1.50	2.25	--------	0.840	Clinton.
44	3	97	99	32.30	39	38	2.71	13.80	3.45	5.17	6.00	1.50	2.25	20.00	0.822	Wheatland.
48	56	44	52	0.79	36	37	11.43	6.20	1.55	2.33	6.00	1.50	2.25	1.07	0.092	DeWitt.
52	2	98	98	49.00	36	38	0.60	13.90	3.48	5.22	6.00	1.50	2.25	30.00	0.828	Davenport.
55	0	100	99	--------	39	38	6.00	14.20	3.55	5.32	6.00	1.50	2.25	--------	0.840	Muscatine.
56	6	94	96	15.70	38	40	13.35	13.40	3.35	5.03	6.00	1.50	2.25	10.00	0.803	Fraser.
59	9	91	87	10.20	35	37	6.80	12.90	3.23	4.84	6.00	1.50	2.25	6.67	0.782	Nichols.
65	17	83	88	4.88	36	38	3.00	11.80	2.95	4.42	6.00	1.50	2.25	3.53	0.719	Vinton.
112	89	11	41	0.12	33	38	1.52	--------	------	------	6.00	1.50	2.25	--------	0.310*	Marshalltown.

*Sand to add.

Group 3, listed in Table IV, contains pit run gravels of such a character that both the 1/8 inch and 1/4 inch sands screened from them is so poorly graded that it is inadvisable to use the material as gravel on work of any importance without their being reproportioned or being mixed with other pit run gravels that will correct the deficiencies in their grading. Most of them are sands and could be used as such if coarse material were added.

Cleanness. In all the discussion of pit run gravels it is assumed that the material does not contain an excess of clay or loam. The percentage of clay by dry measure should not exceed 3% for reinforced concrete work and 5% for mass concrete, not reinforced.

If concrete is to be used for work where weight is the principal requirement and where the load in compression does not exceed two or three hundred pounds per square inch, then any of the pit run gravels of the types of those in Tables II, III and IV may be safely used if the proper amount of cement is added. If, however, gravels are used in reinforced concrete where the loads in compression may reach six or seven hundred pounds per square inch, much more care should be exercised and the concrete should be proportioned as discussed in connection with Tables II, III and IV.

Quantity of Gravel Needed for a Cubic Yard of Concrete. The exact amount of pit run gravel necessary for one cubic yard of rammed concrete is hard to specify since it will depend partly upon the dryness of the gravel when measured and partly upon whether it is measured loose or packed. It is assumed in the following discussion that a cubic yard of pit run gravel, loose measure, makes one cubic yard of concrete. It is also assumed that if sand and stone are measured separately and remixed for making concrete it will require 0.42 cubic yards of sand and 0.84 cubic yards of stone for one cubic yard of concrete. This is not exactly true for all mixtures but is nearly so for ordinary mixtures where the quantity of stone is specified as twice the quantity of sand as in 1-2-4 or 1-3-6 concrete.

REPROPORTIONING GRAVELS.

As an illustration of the foregoing discussion let it be assumed that concrete is to be made from pit run gravel on work for which the specifications provide for a mixture of 1-2-4, but permit the use of pit run gravel if cement is added in such a quantity that the mortar meets the specifications. If the pit run gravel contains more sand than is required there are three alternatives:

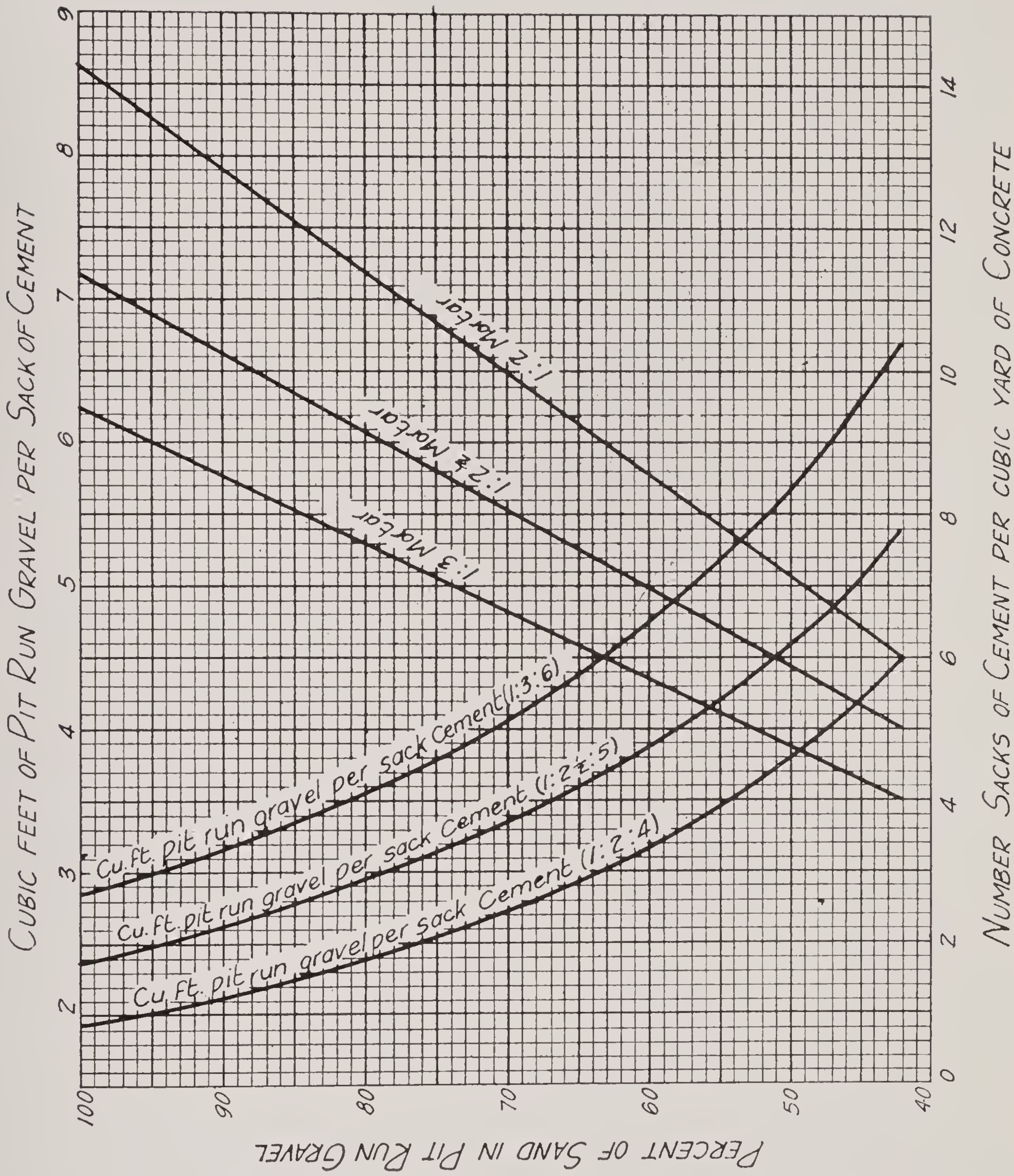


FIGURE 5

1. To add cement so that the mortar will be of the specified strength, that is 1 part cement to 2 parts sand.
2. To screen the gravel and discard the surplus sand, in which case the smallest amount of cement would be used.
3. To add broken stone to the pit run gravel so that the specified ratio of sand to cement would be maintained as well as the ratio of sand to stone. In this case the same amount of cement would be used as in (2).

Which of these three methods will be followed will depend upon their relative cost and that will vary with the relative cost of the various materials and the percentage of sand in the gravel. The following analysis and discussion of a sample of pit run gravel will illustrate the manner in which the most economical method of mixing can be determined.

Cost With Pit Run Gravel. Let it be assumed that the pit run gravel has been analyzed and has been found to contain 60% of sand and 56% of stone and is to be used without reproportioning. The amount of cement to use for one cubic yard of concrete is ½ of the amount of sand in one cubic yard of the pit run gravel or $\frac{27x0.6}{2}=8.1$ cubic feet. Since 1 sack of cement contains 0.95 cubic feet, the number of sacks of cement to use is $\frac{8.1}{0.95}=8.52$

The amount of cement required for 1-2-4, 1-2½-5 or 1-3-6 concrete can be determined from the curves in Figure 5, if the per cent of sand in the pit run gravel is known. Using the case mentioned above as an example and referring to Figure 5, find the percentage of sand at the left of the diagram and follow to the right to the curve marked 1-2 mortar, and read at the bottom of the diagram the number of sacks of cement, in this case 8.52. In like manner the amount of cement may be determined for any other percentage of sand, and for any of the three mixtures given in the diagram.

In comparing the economy of different methods of proportioning, the quantity of cement per cubic yard of concrete is the information desired. When the pit run gravel is used it is desirable to know the amount of gravel in cubic feet that must be used with 1 sack of cement, so that the proper quantity can be placed in the mixer.

Since 27 cubic feet of the above pit run gravel is to be used with 8.52 sacks of cement, the amount of gravel to use with one sack of cement is $\frac{27}{8.52}=3.16$ cubic feet. This quantity can also be determined from the diagram in Figure 5 as follows: Find the percentage of sand at the left of the diagram and follow to the right to the curve marked "Cubic feet of pit run gravel to use with one sack of cement, 1-2-4 mixture" and read at the top of the diagram the number of cubic feet of pit run gravel, in this case 3.16. In like manner, the quantity can be determined for any other percentage of sand and for either of the three mixtures given.

If cement costs $1.50 per barrel and the pit run gravel costs 25c per cubic yard, the cost of cement and the above gravel per cubic yard of concrete is:

Cement $\frac{8.52}{4} \times 1.50 =$ $3.19

Gravel 0.25

$3.44

The cost for cement and aggregate may also be determined from the diagram in Figure 6. At the left of the diagram find the percentage of sand which in this case is 60, and follow to the right to the curve marked "pit run gravel at 25c per cubic yard" and read at the bottom of the diagram the cost for cement and aggregate for one cubic yard of concrete, which in this case is found to be $3.44.

In the same way the cost for cement and aggregate can be determined for any other percentage of sand. If the mixture is 1-2½-5 the cost can be obtained from Figure 7 and if 1-3-6, from Figure 8.

Cost With Screened Gravel. Having the cost of cement and aggregate for one cubic yard of concrete, using the pit run gravel, the next step is to find the cost of cement and aggregate for one cubic yard of concrete if the excess sand is screened out and discarded. Since the amount of sand required for one cubic yard of concrete is 0.42 cubic yards, and the amount of stone 0.84 cubic yards, the amount of the pit run gravel that must be screened to furnish enough stone for one cubic yard of concrete may be determined as follows:

The amount of stone needed is 0.84 cubic yards and 1 cubic yard of the pit run gravel contains 0.56 cubic yards of stone, therefore, the amount to screen is $\frac{0.84}{0.56} = 1.5$ cubic yards.

The amount to screen may also be determined from the curve in Figure 9 as follows: Find at the left of the diagram the per cent of sand in the pit run gravel and follow to the right to the curve marked "Gravel to screen" and read at the bottom of the diagram the number of cubic yards to screen, which in this case is 1.5.

In like manner the number of cubic yards to screen can be determined for any percentage of sand. The curve holds good when the amount of coarse aggregate is specified to be twice the amount of sand, regardless of the amount of cement specified.

The cost of the aggregate for a cubic yard of concrete depends upon the cost of the pit run gravel, the cost of screening and whether the surplus sand must be paid for or may be left in

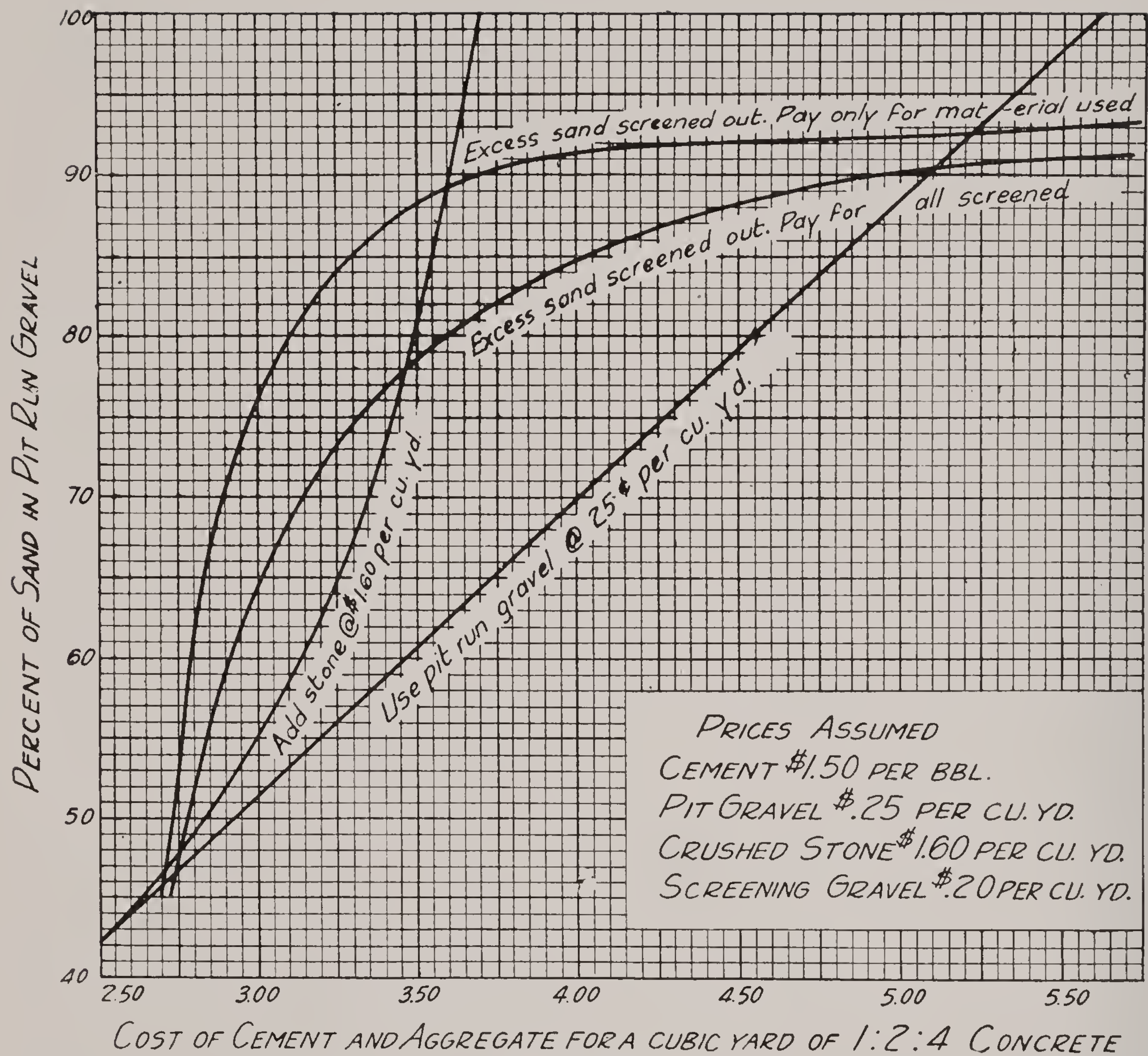


FIGURE 6

the pit and not paid for. Assume that pit run gravel costs 25c per cubic yard, that the surplus sand need not be paid for and that screening costs 30c per cubic yard, and that cement costs $1.50 per barrel, and the cost of cement and aggregate for one cubic yard of concrete will be as follows: The cost of cement will be as follows: Since 0.42 cubic yards of sand will be used, 0.21 cubic yards of cement will be used, or 5.67 cubic feet, and since a barrel of cement is 3.8 cubic feet, the number of barrels of cement required is $\frac{5.67}{3.8}=1.49$, or say, 1.5 barrels.

Cost of cement 1.5×1.50=	$2.25
Cost of 1 cu. yd. pit run gravel	0.25
Cost of screening 1.5 cu. yd	0.45
Cost of aggregate per cu. yd.	$2.95

If the surplus sand must be paid for it will add to the above the cost of 0.5 cubic yard sand discarded, or 12½c, making the cost of the aggregate for one cubic yard of concrete $3.07.

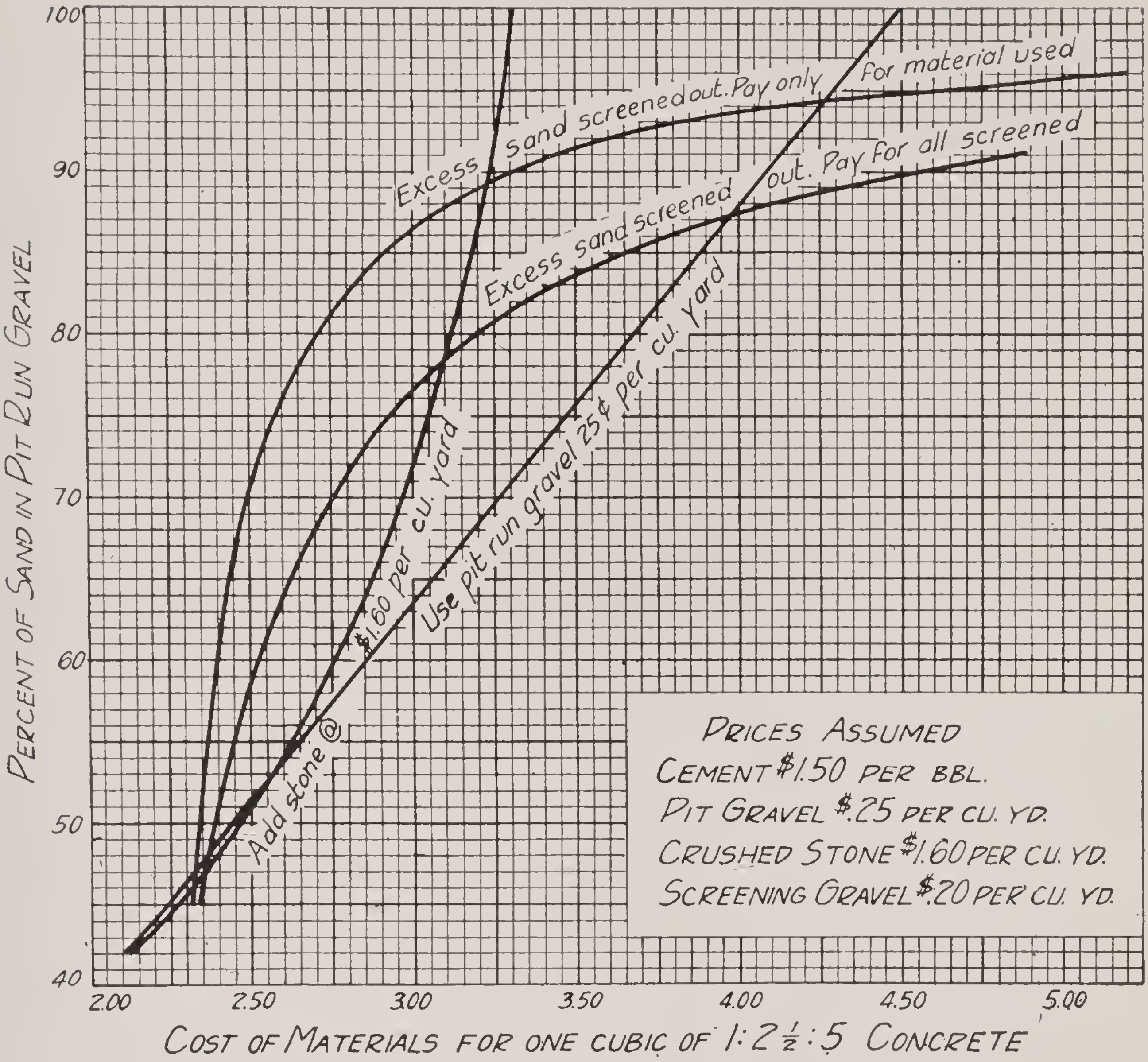


FIGURE 7

The cost of aggregates for a cubic yard of concrete when the percentage of sand is known and when the mixture is 1-2-4, 1-2½-5 or 1-3-6 can be read from the diagram in Figures 6, 7 and 8.

These diagrams also give a curve of costs when all material screened must be paid for and are used in the same manner as the curves already described which are given in Figure 6.

Cost When Stone Is Added. If crushed stone is available, it may be cheaper to add it to make up the deficiency in coarse material than to screen the gravel. To determine the quantity of stone to add for one cubic yard of concrete, the amount of the pit run gravel to use to furnish the proper quantity of sand must first be determined. Since it requires 0.42 cubic yard of sand for a cubic yard of concrete and each cubic yard of the pit run gravel contains 0.6 cubic yard of sand, the quantity of the pit run gravel needed to furnish sand for a cubic yard of concrete is $\frac{0.42}{0.6} = 0.7$ cubic yard.

Since the pit run gravel contains 56% of stone, there will be in the 0.7 cubic yards of pit run gravel 0.7×0.56 or 0.392 cubic yard of stone, and since 0.84 cubic yard of stone is needed for a cubic yard of concrete it will be necessary to add to the 0.7 cubic yard of pit run gravel $0.84-0.39=0.45$ cubic yard of stone. The cost of the materials for one cubic yard of concrete will, in this case, be as follows, assuming the stone to cost $1.60 per cubic yard:

Cost of pit run gravel, 0.7×0.25=	$0.17
Cost of stone to add, 0.45×$1.60=	0.72
Cost of cement, 1.5×$1.50=	2.25
Cost material for 1 cu. yd. of concrete	$3.14

The amount of stone to add to pit run gravel containing any percentage of sand, to give material for one cubic yard of concrete, can be obtained from Figure 9 by finding the percentage of sand at the left of the diagram and following to the right to the curve marked "Amount of stone to add to pit run gravel" and reading the quantity to add at the top of the diagram. It should be noted that if the sand content of the pit run gravel is less than 42%, then sand must be added as indicated in the diagram or some of the stone must be screened out of the pit run gravel and wasted.

Now, having determined the cost of the aggregate for one cubic yard of concrete by each of the three methods of proportioning the pit run gravel under discussion, the most economical can be chosen. For convenience the three possibilities are summarized as follows:

COST PER CUBIC YARD OF CONCRETE FOR AGGREGATE AND CEMENT.

1. Use without reproportioning............$3.44
2. (a) Screening out and discarding surplus sand and paying only for gravel used 2.95
   (b) Screening out and discarding surplus sand, but paying for all gravel screened 3.07
3. Adding crushed stone.................. 3.14

It will be seen that the cheapest method is to screen out and discard surplus sand, if only material used is paid for. If all gravel screened must be paid for it is still cheaper than to add stone, although the difference is slight. It is by far the most expensive to use the pit run gravel without reproportioning.

Conclusions. The relative costs of the three methods outlined will vary with the costs of materials and the cost of labor, and for any given set of conditions these costs must be worked out before a decision can be reached, as to the most economical

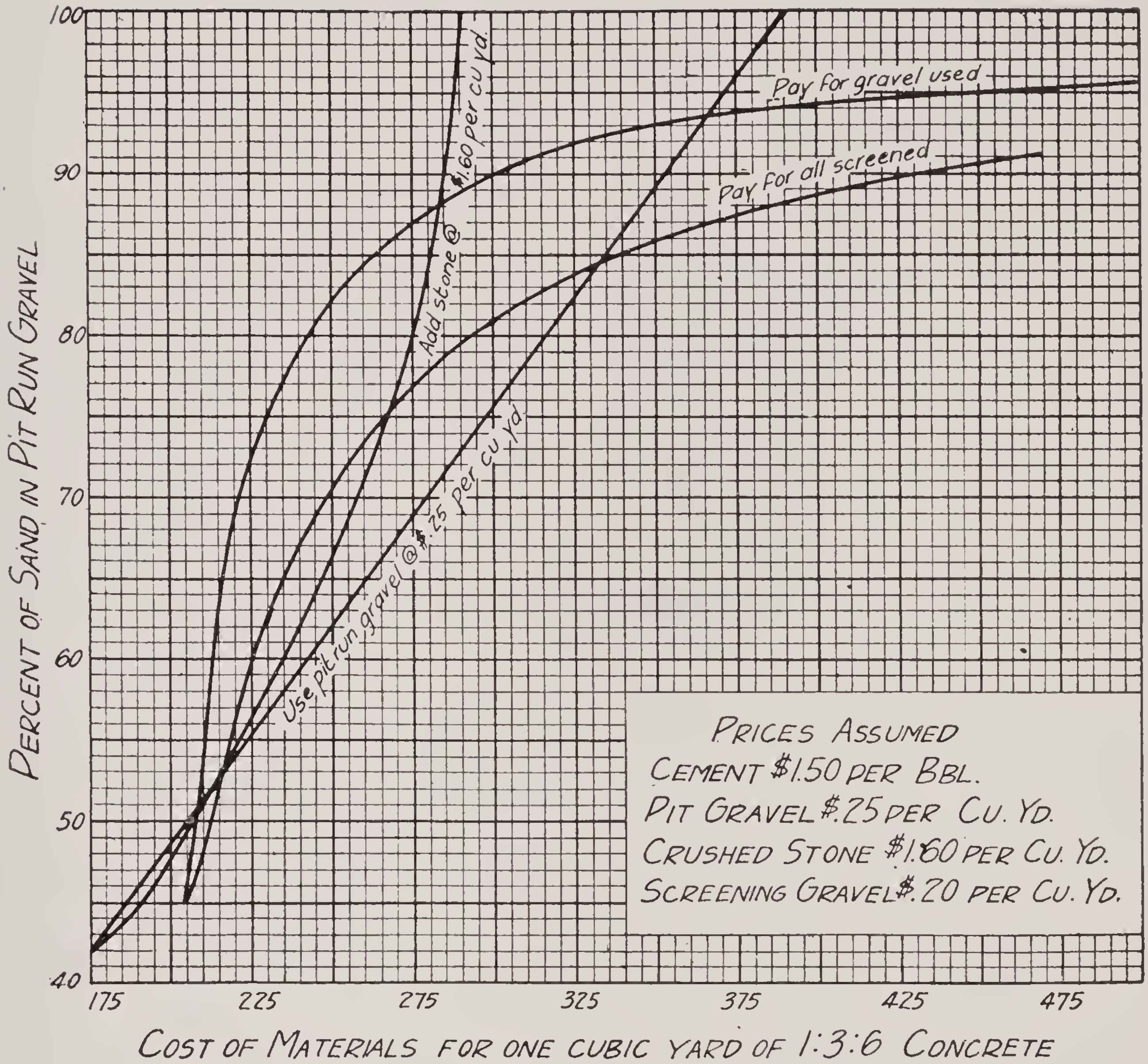


FIGURE 8

procedure. The quantities of materials can readily be determined from curves shown in Figures 5 and 9 and the costs can then be determined when the price is known.

A study of Figure 6 which applies to concrete mixed in the proportions 1-2-4 and with materials at the prices indicated on the diagram, shows that if the sand content of the gravel is more than 50% and less than 95% it pays to screen and reproportion. It also shows that it is much cheaper to add crushed stone than to use the pit run gravel. If the sand is above 80% it is cheaper to add stone than to screen if the surplus sand must be paid for. In the same way it can be seen from Figure 7 that for 1-2½-5 concrete with materials at the prices indicated on the diagram, if the percentage of sand is less than 50% there is no great saving to be obtained by reproportioning, but if the percentage of sand is between 50 and 95 it will be a decided saving to screen. The diagram also shows that if all the material screened must be paid for, including the surplus sand, then if the sand content is greater than 75% it will be cheaper to add stone than to screen the gravel.

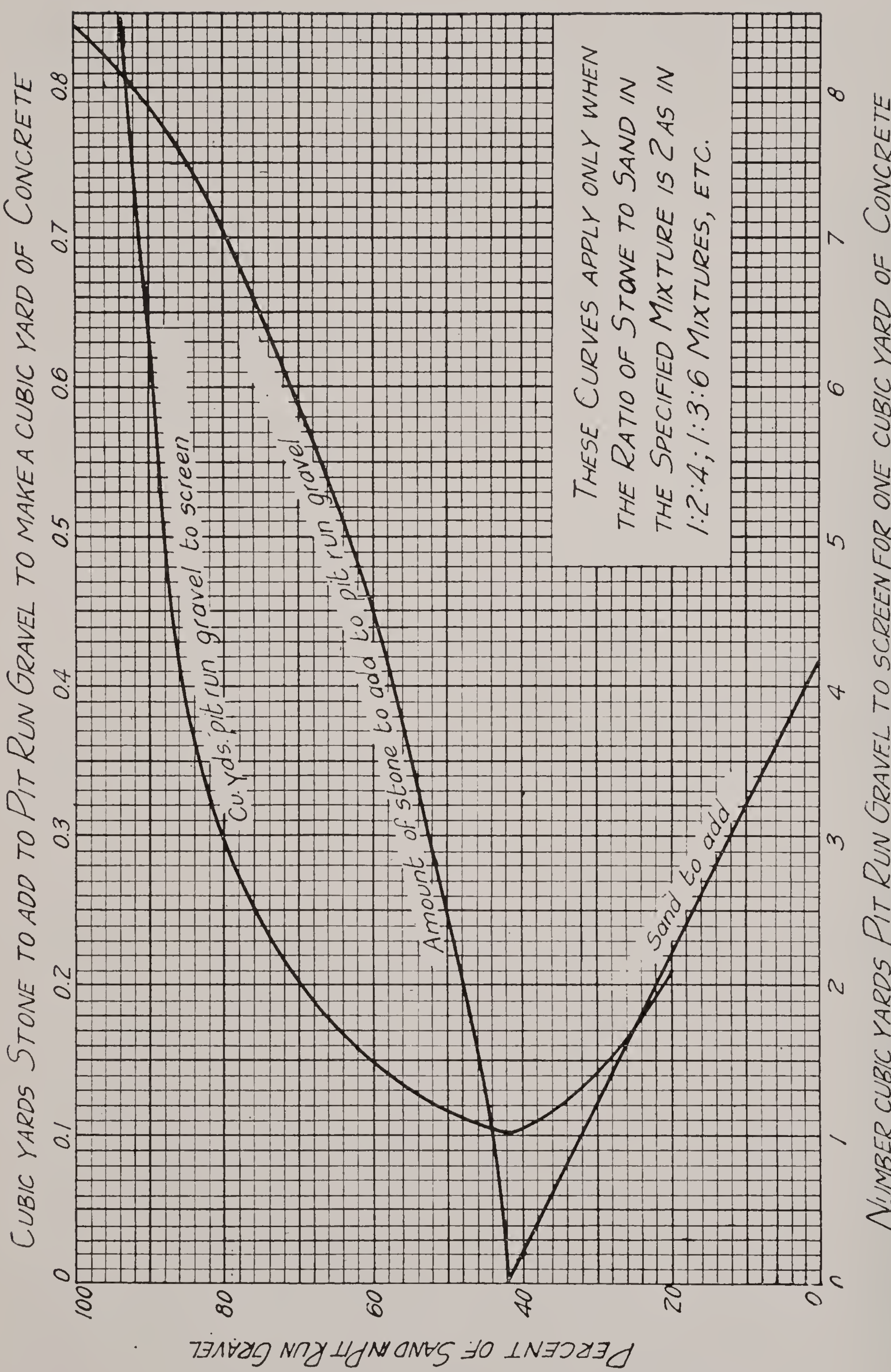


FIGURE 9

Similarly, Figure 8 shows that for a 1-3-6 concrete with materials at the prices indicated on this diagram, it pays to screen, if the sand content exceeds 55% and is less than 93%. It also shows that if all material screened must be paid for it is cheaper to add stone than to screen if the sand content exceeds 75%, and if only the material used is paid for it is cheaper to add stone than to screen, when the sand content exceeds 88%.

These relations hold true whether 1/8 inch or 1/4 inch sand is used and the decision as to which size will be adopted for sand depends upon the size of the coarse aggregate as previously explained.

If the 1/4 inch sand is used more cement will be required with pit run gravel than if 1/8 inch sand is used, but in case of doubt, use the 1/4 inch sand.

It should be noted that the typical cases worked out in the preceding pages give results which are comparable only when the prices paid for pit run gravel, crushed stone, screening and cement are as indicated. For other prices the quantities can be determined from Figures 5 and 9, the cost computed as outlined in the illustrative example. The computations are simple and the tests can readily be made in the field and adjustments in the methods of proportioning made in accordance with the tests.

In this connection it should be noted that for concrete roads or pavements the pit run gravel should, in every case, be screened and the sand and stone thus obtained used for the concrete. Pit run gravel should never be used for concrete road or pavement construction.

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